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Virtual Reality Use in Architectural Design Studios: A case of studying structure and construction

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Abstract

This research applies micro-simulation function, with XML algorithms made by the researcher, inside a virtual reality environment, the VR Studio programme. The research utilises this function of the VR program in architectural design studios. The main objective is to investigate how and to what extend students would benefit from applying this new potential of the VR function. The hypothesis was that the function potential would assist students to have more understanding of the structural system selected, which would be simultaneously beneficial on the architectural design level.
The students used the VR programme during the design process in the stage of proposing and exploring the structural system. The used application focuses on providing the students with an effective tool to select and visualise a structural system and its construction process. A questionnaire was designed and distributed to the students to record their remarks and opinions of using the VR function. The questionnaire replies indicate and open more areas than the hypothesis.
The research methodology is to use mainly qualitative analysis and secondarily quantitative analysis, to have evaluation that indicates the effectiveness of Virtual Reality as an educational tool in the architectural design studio. The research employs the VR Studio programme in order to introduce new visualization potentials other than what are currently used. The research concludes to solid results of the use of VR in the architectural design studio, and proceeds further to open new research venues.

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Keywords: Virtual Reality ; Design Studio; Architectural Education; Micro-Simulation.

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1. Introduction

Virtual Reality can be defined as "A human-computer interface in which the computer creates a sensory immersing environment that interactively responds to and is controlled by the behaviour of the user" [1]. This definition is produced by the students of The Human Interface Technology Lab at the University of Washington, from Encyclopedia of Virtual Environments.

1.1. Virtual Reality and learning

Virtual Reality environments have experiential nature that derives from three sources: immersion, interactivity and multi-sensory feedback. The first two sources are more related to the research area. In Immersion, a user is surrounded by the environment in a way that ensures a sense of presence or the feeling seen really in the depicted world [2]. Interactivity can be seen as the ability to control events in the simulation environment by using human body movements which in turn initiate responses in the simulation environment as a result of these movements [3].

The experiential nature of VR supports a constructivist approach to learning [4]. Constructivism is a theory of knowledge acquisition in which humans construct knowledge by learning from their experiences. Humans learn by having experiences and using their senses to derive information from the world [5]. Virtual Reality is a technology that replaces sensory input derived from the real world with sensory input created by computer simulation. VR help in teaching by providing an environment that allows the users to experience scenarios and situations rather than imagining them.

Learning is a form of active hypothesis testing, which should be contrasted with the view that learning is a passive accumulation or acceptance of facts [6]. VR provides a learning environment to test the active hypothesis, and therefore provides a powerful medium for learning. In general, and as proposed by the research, humans/users who actively engage with new knowledge are more likely to retain this knowledge and recall it at a later stage, and furthermore they have more awareness of this knowledge.

VR that can be employed in learning/education processes, by replacing the often impractical constraints associated to real situations, and in this regard humans explore different experiences and scenarios in the VR environment by facing a wide range of situations instead being limited to the real or the possible. Humans benefit from these potentials of VR use, which subsequently improve the learning/education processes.

1.2. Virtual Reality in design studios

The most common use of Virtual Reality in architecture has been to enhance the experience of walking inside or around a structure that does not exist. VR researchers have worked toward making VR an effective tool for design creation and design exploration. Recently, VR has been extensively used in designing to visualise different design solutions for one main reason that it is much easier and cheaper to evaluate the form and design in a virtual environment instead of building or modifying a physical model.

In addition to visualising the virtual environment, VR systems can be used as a tool to build up the design model and its surroundings, in other words the virtual environment itself. Designers and architects have adapted Virtual Reality into the design process and architecture creation and use it to explore a design with its spatial relationships and its surroundings. By applying the same concept, Virtual Reality is used in architecture education in the designing process, where it provides a designer a full image of spatial relationships of design components instead of depending on raw imagining. In other words, VR has this particularity that helps to create the spatial and topological relationships of a design.

In the VR work made by using the Calibre Institute environment, VR has been used since 1991 as an experimental tool to assess the impact of VR technology in design [1]. The VR technology was further developed in Calibre to become an important presentation tool in student projects for assessing design variants and final design solutions. Since 1997, VR was used in the whole of the design process in a number of student projects of Calibre introducing a quantum leap of use, which has lead to an increasing number of innovative student projects [1]. VR has been used as a design support environment, providing creative and innovative potentials [7].

2. Structure visualisation in Virtual Reality

The researcher has developed algorithms in XML in a new function that can be used in the micro-simulation player of the VR environment, VR Studio programme. The function goal is to visualise the construction process of a structural system in a certain order. This new function enables the visualisation of any possible change in the construction order by changing XML code in an easy way. This area, construction management visualisation in Virtual Reality, has been previously investigated in two researches of the author, Fig 1 [8].

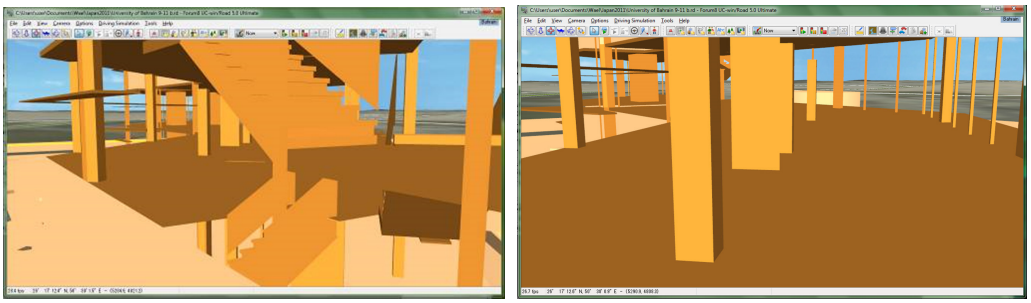

Fig. 1. two screenshots of VR program showing structural elements at a certain stage of a construction process

More explanation of this introduced function and its potentials have been presented in practical case studies, Fig 2 [9].

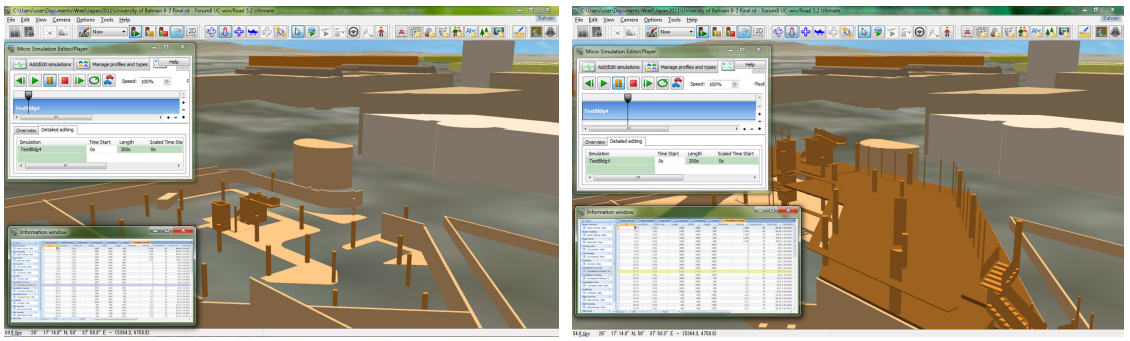

Fig. 2. (a) ground floor of a structural system; (b) 2nd floor of a structural system

This research introduces an application of the new VR function. The application can be employed in the design studio, design process and structural design. The virtual reality environment used in this study and research is the Virtual Reality Studio programme developed by Forum8, the Japanese company.

3. Architectural design studio

The study is conducted into two design studios of the same design complexity at intermediate design level. The design projects are Business Centre and District Museum. Applying the study in two different design studios was to measure more responses of students. The two architectural programmes/briefs including their components were defined by the students/subjects. The two architectural programmes have approximately the same level in terms of the number of zones and components, built areas, functional relation complexity. The students/subjects optionally choose their project sites from different sites of approximately the same area.

This intermediate level of the two design studios comprehensively covers the structural system and the construction process. Students are required in this design level to provide and present the details of the structural system in their designs in terms of type, spanning, structural elements and expansion and settlement joints. The structure requirements of previous design studios did not include a whole structural system where students used to select the system type and show the structural elements/columns in only plan and elevation drawings.

Students are also required to propose the construction scenarios to their structural systems. At the beginning of the design studios, they were research groups of 2-3 students to conduct a structure/construction research that investigates the structural system types and details. This design studio task is beneficial to the students not only to their structural and constructional knowledge but also to highlight how the structural system that is initially selected would affect the design.

3.1. Studio development

During the phases of problem definition and conceptual designing, the students selected any design medium in designing. At this stage, students/subjects created initial designs with tentative forms. Having initial forms and designs, they made digital models in order to be used in the Virtual Reality programme. Digital models were built by different modeling programmes, for example 3ds max, Sketch Up, AutoCAD. The VR programme is used in student projects in the next stage after almost completing conceptual designing. There were lectures and presentations in the design studio to explain for students how to import and export the digital models, and how to use the main functions of the VR programme.

The design studio aims at improving students' knowledge of structural systems employed in designing. Students were required to explore and propose in the VR environment the structural systems that would be used in their designs, Fig 3. During the use of VR, students were asked to record their design developments and modifications. While using the VR programme, students either went forward into the design process to finalize the structural system under investigation, or went backward to change and modify the structural system or even the initial form and design itself.

After selecting and exploring the structural systems, the students started to finalize their designs and spatial relationships. At this phase end, design forms are completed and students started elevation treatment and design In this phase, some students continued by using digital media, the VR programme and different modeling programmes, while other students made elevation treatment and design by using manual media.

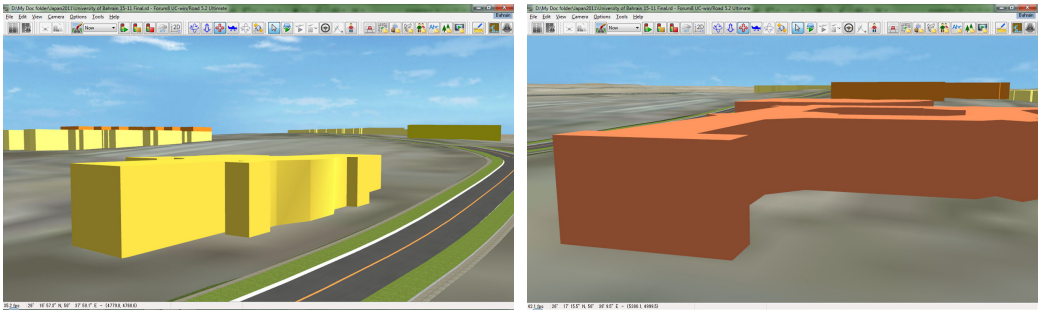

Fig. 3. two student work examples in the VR program at the beginning stage of VR use

3.2. Methodology

The study aims at investigating the VR use in selecting and designing the structural system in students' design projects. In order to achieve this goal, a simple methodology is applied by highlighting the changes that students make in their designs and structural systems as a result of VR use. The development and modification of both designs and structural systems are recorded by students/subjects and classified by the instructor/researcher, which enables to easily track and evaluate transformational steps of the decision-making rationale and the reasoning.

The students were asked to provide self-records of each explicit stage and action. These explicit sequence records with the supplementation of students' textual explanations were used to expose differences in the development of structural systems from one design case to another. Students made presentations to evaluate their work and present inside explanations of the design process. This exposure to different ways of VR applications was an objective by itself of the design studio.

4. Questionnaire

Questions were designed to highlight the effect of VR on how students select and design the structural system and in the same time record the effect of structural system on their architectural designs. Any change resulted from the VR use, whether forward or backward in students' design processes was recorded.

The questionnaire is divided into four question groups. The first group of questions investigates the effect of VR use on the structural system selection. The questions aim to measure whether students change the structural system after visualising it inside the design or not. Second, how the structural system elements and their locations in the design are explored and evaluated by the students. This part also covers the expansion and settlement joints, and how they are designed. Third, to select the constructional ways and the proposed constructional scenarios, this area is one of the design studio objectives which is discussed and highlighted for the students through presentations. The fourth group of questions concentrates on the relationship between the structural system and the architectural design. How the structural system may change the architectural design and spatial relationships in case of any modifications in the structural system.

4.1. Respondents

The subjects/respondents are in the third academic year of the architecture program that is a five year study. Subjects have finished all courses of Architectural Construction, two courses, in their previous study years. The

total number of students/respondents is thirty nine; one design studio has twenty students while the other has nineteen.

4.2. Analysis and results

At the beginning stage of VR use, students included their structural systems in the initial digital models that were abstract and did not have much detailed forms, Fig 3. The instructor explained to the students how to use VR programme and its commands to explore the models. This step was to ensure that students completely comprehended, and were familiar with the method applied. Starting to use the VR programme, each student explored the structural system and its elements. In most cases changes were made in structural designs and architectural designs while some students just had more clarity of the used structural system which resulted in only architectural design modifications.

Quantitative analysis generated from the subjects' models was analysed in figures. Qualitative observations and analysis were necessary to explain both trends and remarks in the quantitative results of the questionnaire. The students made a wide range of modifications in both levels: structural and architectural designs, which varied in many ways, see Fig 4. The questionnaire analysis and results and further discussion are in the following part according to the four question groups:

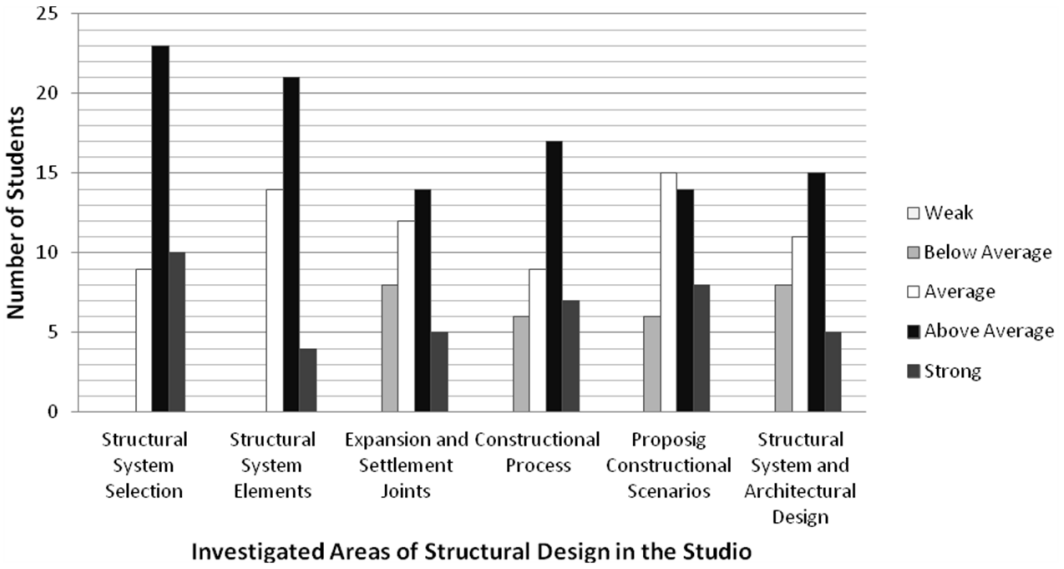

Fig. 4. questionnaire results analysis

4.2.1. Structural system selection

Around fifty nine percent of the respondents find that the VR use has above average effect on their selection of the structural system, while the rest of the students are divided between average and strong effect. No weak or below average effect has been recorded.

The effectiveness of VR use is evident in the design cases of students who used a different structural system other than what has been selected at an earlier stage, Fig 5. This observation presents VR as the more suitable medium during form and design development.

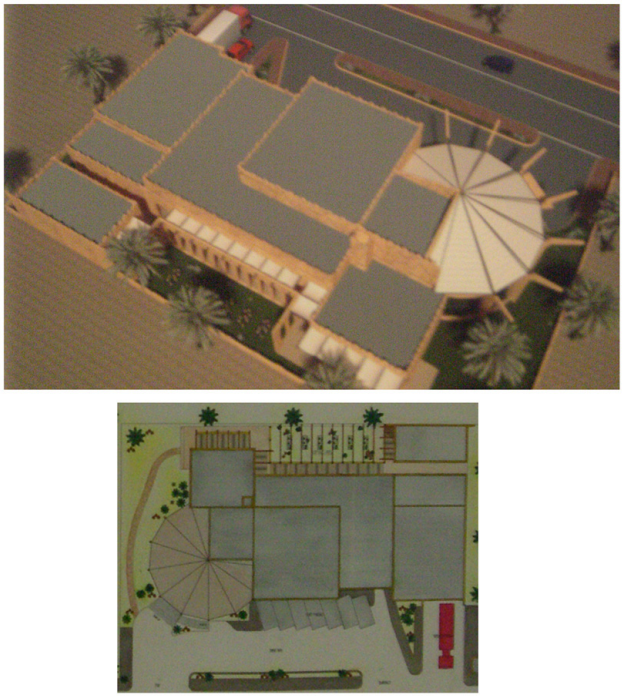

Fig. 5. a student work example showing the structural system effect on a cylindrical part of the design

4.2.2. Structural system elements and expansion and settlement joints

The majority of respondents record the effect of VR use as above average while the rest of respondents were divided into below average, average and strong effect. No weak effect has been recorded.

In their remarks and during discussions of the studio, the students stated that they had more clarity on the connections and spatial relationships of the structural system elements while using the VR environment. In the same time, the spatial relationships between these structural elements and other design elements and components were better investigated and visualised, Fig 6.

Having this clarity, the students propose and then decide locations of the expansion and settlement joints in the design, Fig 6. The VR environment was such an effective medium for the students while performing this particular task. In some design cases, the spatial connections of these joints were more complicated than other design cases. The virtual reality environment helps to visualise spaces of the design and their architectural and structural elements.

4.2.3. Constructional processes and their scenarios

Around forty four percent of the respondents find that the VR use has above average effect on the constructional process itself, while around thirty six percent of the respondents find that the VR use has above average effect on proposing the constructional scenarios. On the other hand, around thirty eight percent of the respondents indicate that the VR use has an average effect on proposing the constructional scenarios.

Students started to propose constructional processes and visualise these processes with different scenarios in the VR environment. The students who have more simple structural systems and designs indicated average effect of the VR use.

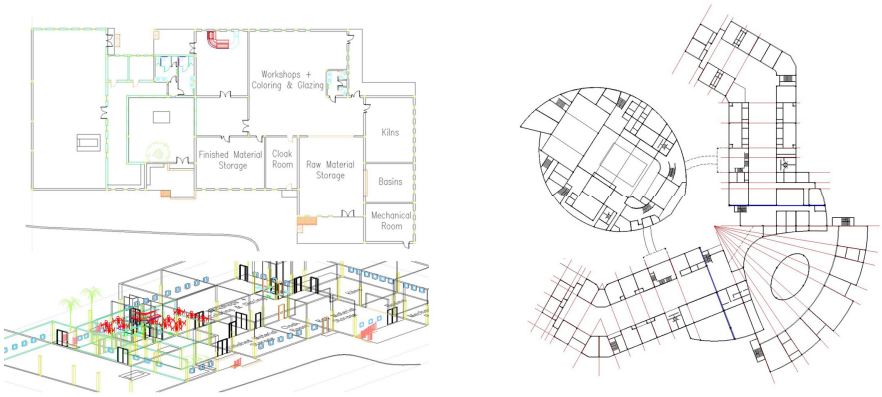

Fig. 6. two examples (a) relationship of structural elements and other design elements; (b) expansion joints effect on the design

The nature of virtual reality helped students in the processes of imagination, particularly in perceiving and conceiving the third dimension of forms, design components and structural elements, Fig 7. This observation indicates the appropriateness of VR use in designing more than mere modeling.

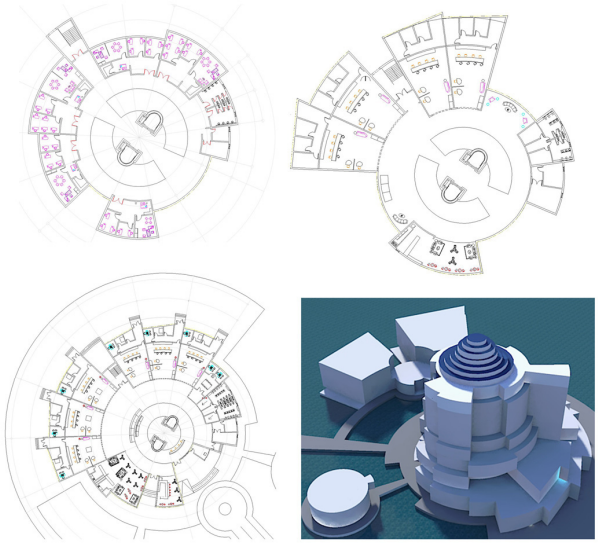

Fig. 7. an example of a complicated form and many design elements; resulting in many possible construction processes

4.2.4. Relationship between structural system and architectural design

Around half of the respondents record the effect of VR use as above average and strong while almost half of the respondents view the effect of VR use as average and below average effect. No weak effect has been recorded.

This observation partially resulted from the abstract level of forms used by students at the beginning. With the VR use, students created more details and modifications inside their designs. Each detail/modification was numbered in sequence by student. The students' design activities, detailing or modifying, were grouped in order

to have an indicator of VR use. Most students chose to make final modifications of form and facades in the computer modeling programmes they used earlier. This trend resulted from the new method of VR use; students therefore preferred to use their own old design methods, Fig 8.

Some designs were developed and modified in more steps than other designs. The back-forth movement varied from one design case to another, reflecting the difference in the VR use effect. This observation could be related to the fact that visual design thinking used in designing and design problem solving varies from one designer to another [10]. The back-forth movement in many design cases was more, which refers to more modifications in the architectural designs.

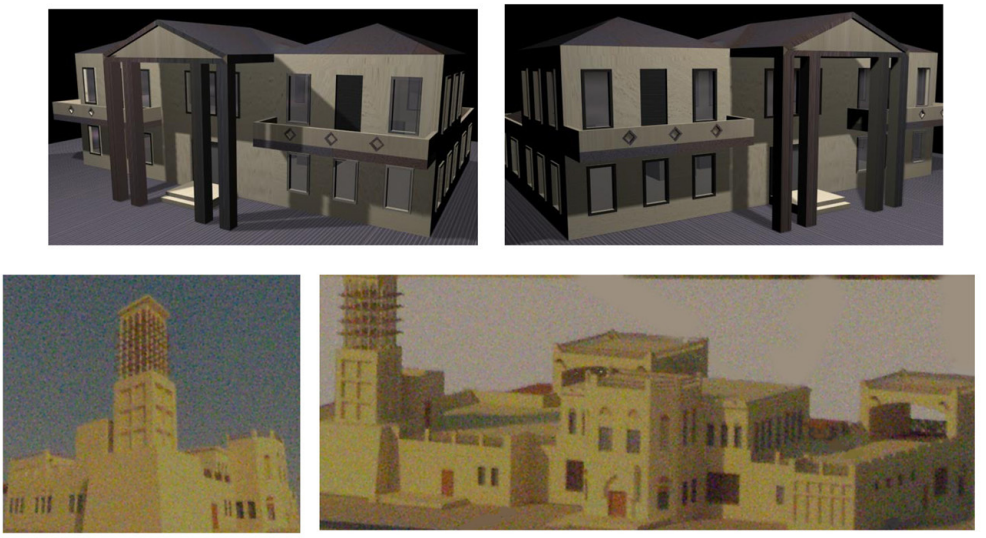

Fig. 8. two design examples with final design details by using AutoCAD and 3ds max

5. Discussion

From textual explanations and self-records of the students, much variety in levels of virtual reality use and visual design thinking was evident among the students. However, both the simple methodology applied and the various design factors neutralized, overcome the effect generated from human variation and creativity.

The advantages of employing Virtual Reality as a design medium have been appeared in students' textual explanations. Students highlighted few areas in using Virtual Reality in their discussions and presentations throughout the studio. There were more and high awareness of the structural system and its elements during design activities.

The Virtual Reality use is interrelated with individual ways of visual design thinking used by students in designing. Indeed, each designer uses the virtual reality environment in a way that fits his/her visual design thinking. In other words, the individual subjective way of visual design thinking and perception that varies from one designer to another has a recorded effect on the result and output of the VR use. Students who have more experience in modeling computer programmes, become easier and faster more familiar with the VR environment, which leads to effective and more modifications in both structural and architectural levels, Fig 9.

Fig. 9. a student case study with final design details by using VR Studio and 3ds max

6. - Conclusion and Future Work

The research aims at investigating the use of the Virtual Reality environment in visualisation of the structural system and its constructional process during designing in architectural design studios. This study has confirmed that the VR use is beneficial in the designing phase of the structural system. The VR use increases the awareness of designer during designing in terms of the structural properties and component assembly of the structural system.

Virtual reality is an effective design medium. Perhaps more than any design medium, virtual reality facilitates selective reinterpretation and immediate evaluation. Virtual reality also allows designers to oscillate easily between design elements properties, abstract representation, and component assembly of the structural system in a single design activity. These relationships need more investigation and research to be explored and measured.

On the other hand, Virtual Reality eases imagination and therefore highlights the relationship between architectural design and its structural system. How the structural system affects the architectural design and form, is an important part of this relationship. More investigations and researches should be also directed to this area.

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